Dynamic Modeling for Project Management

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Agenda

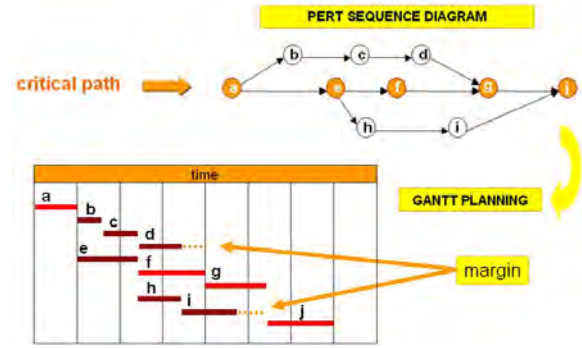
- Defining characteristics of current large product development projects
- Technical demands on project management and limitations of most-used project management techniques
- How dynamic modeling has helped The Aerospace Corporation

Defining characteristics of large product development projects

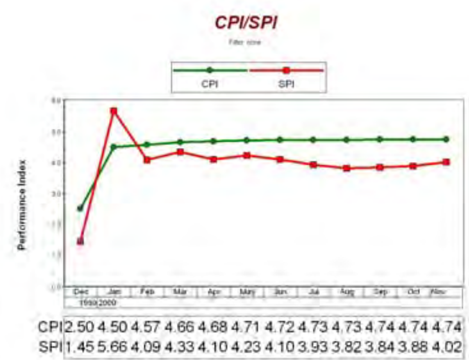
- Structural complexity
  - *Multiplicity of elements (organizations, resources, tasks, etc.)*
  - *Various types of interdependency*
    - Pooled (resources)
    - Sequential (tasks)
    - Reciprocal (feedback)
- Uncertainty
  - *Goal (requirements)*
  - *Methods (processes)*
- Tight time-constraint
  - *Underestimation*
  - *Political factors*

State of the Practice in Project Management

- Existing
  - *Models activities and dependencies*
    - PERT charts
    - Gantt charts



  - *Resource leveling*
    - Project management software, e.g., Microsoft Project
  - *Earned value management*
    - Lagging indicators of progress



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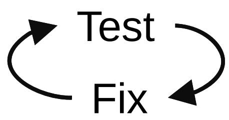
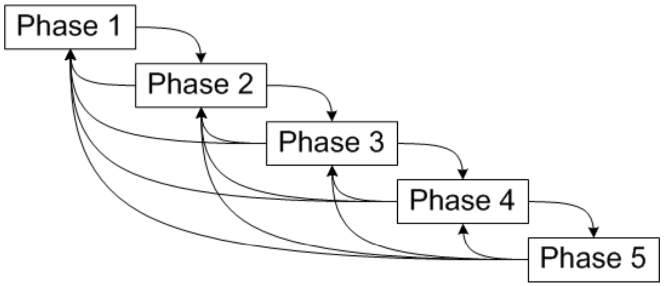
Challenges to Project Management Current Practice

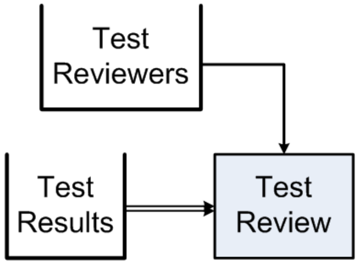
- Feedback



- Downstream effects of quality problems



- Effects of waiting for work products and resources



- Intangible factors
  - *Schedule pressure*
  - *Morale*
  - *Overtime effects*

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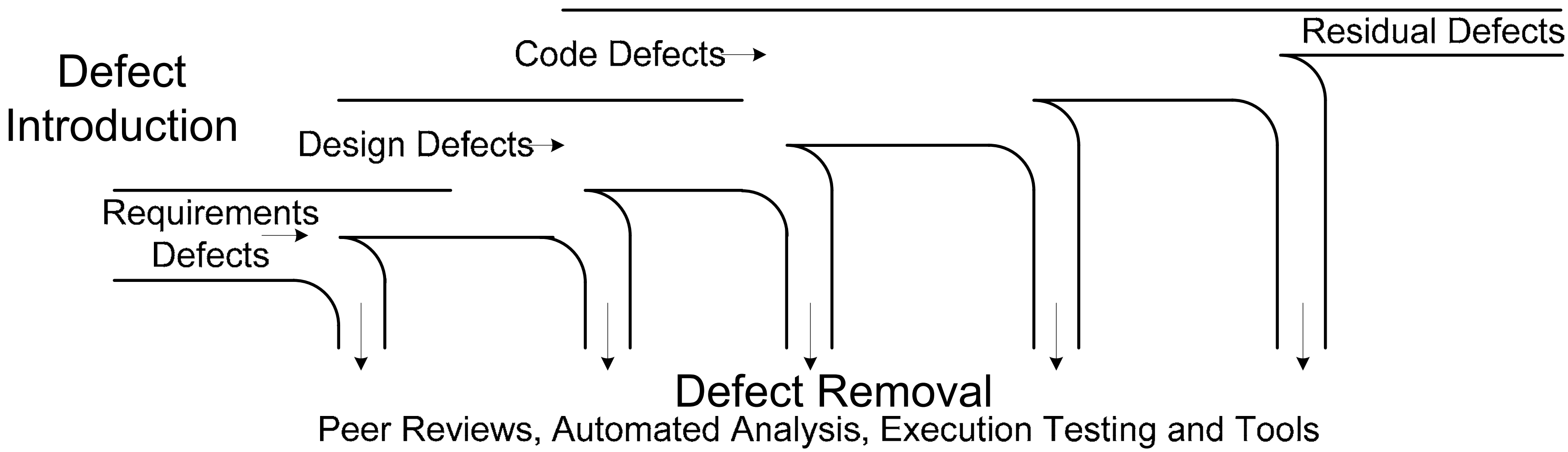
How dynamic modeling has helped The Aerospace Corporation

- Program office support
  - *Lessons learned with Dynamic COQUALMO*
  - *Test and fix modeling*
- Acquisition planning
  - *Modeling probabilities of successful completion*
- Research
  - *Study of concurrent processes*

Lessons Learned with Dynamic COQUALMO

COQUALMO



- Extension of COCOMO II
  - *Relates defectivity to cost and schedule*
  - *COCOMO II drivers are treated as quality drivers*
  - *Quality measured in counts of non-trivial defects (critical system function impairment or worse)*
- Submodels
  - *Defect introduction*
  - *Defect removal*

COCOMO II and COQUALMO were developed at the Center for Systems and Software Engineering of the University of Southern California.

Defect Introduction Submodel

- Sources of defects: Requirements, Design, and Code

$$DI_{source} = DIR_{source,nom} * Size^{B_{source}} * \prod_{i=1}^{21} DefectDriver_{i,source}$$

- DI = defects introduced from each source
- DIR_{nom} = nominal defect introduction rate by source
- $Size^{B}$ = software size raised to scale factor by source
- Defect Drivers in Quality Adjustment Factors (QAFs)
  – *Example: Analyst Capability (ACAP)*
- Defect driver values produced through a two-round Delphi process.

ACAP Level	Requirements	Design	Coding
Very High	.75	.83	.90
High	.87	.91	.95
Nominal	1.0	1.0	1.0
Low	1.15	1.10	1.05
Very Low	1.33	1.22	1.11

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Defect Removal Submodel

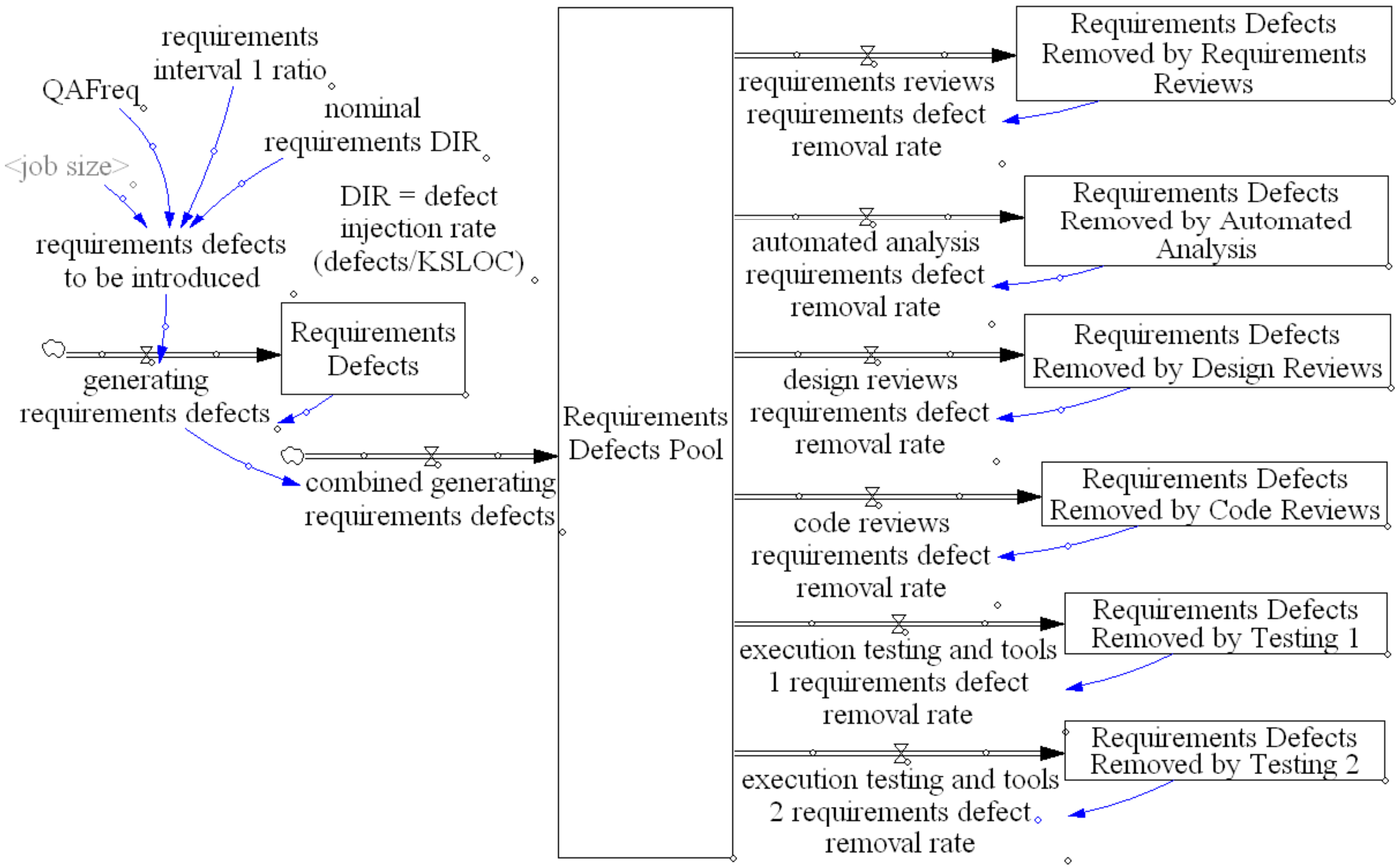
- Defect removal activities: peer reviews, automated analysis, testing

$$DR_{artifact} = DI_{artifact} * \prod_{i=1}^{3} (1 - DRF_{i,artifact})$$

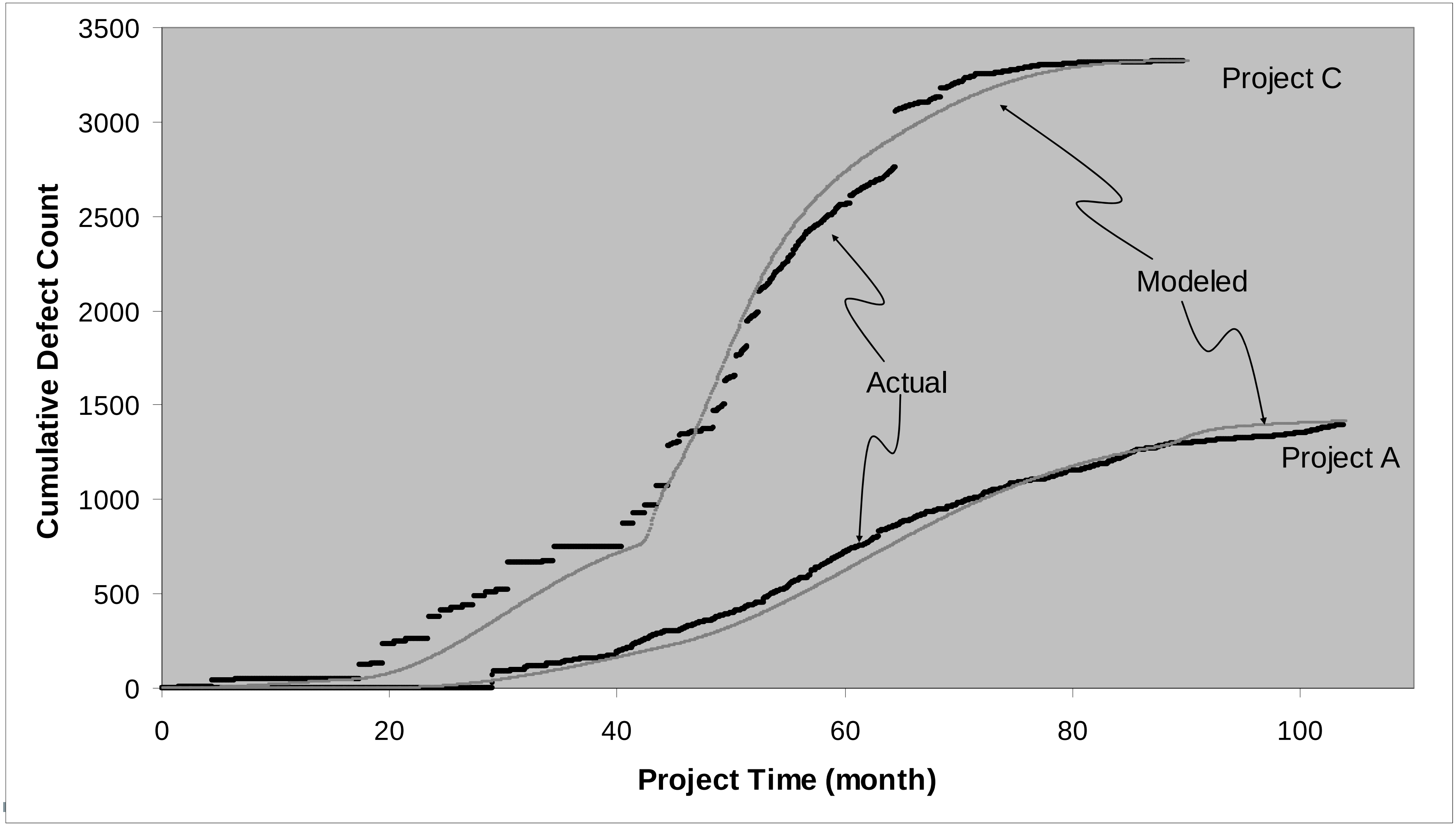
- DR = defects removed from artifact
- DI = defects introduced into each artifact
- DRF = removal fraction for each activity, *i*, applied to each artifact
- DRF assigned to quality levels of activities in 2-round Delphi

Model Description: Defect Flows

- Three inflows, one each for requirements, design, code
- Outflow for each review type, automated analysis, and testing phase
- Flows arrayed by interval



Major Defect Discovery Profiles for Projects A & C, actual and modeled



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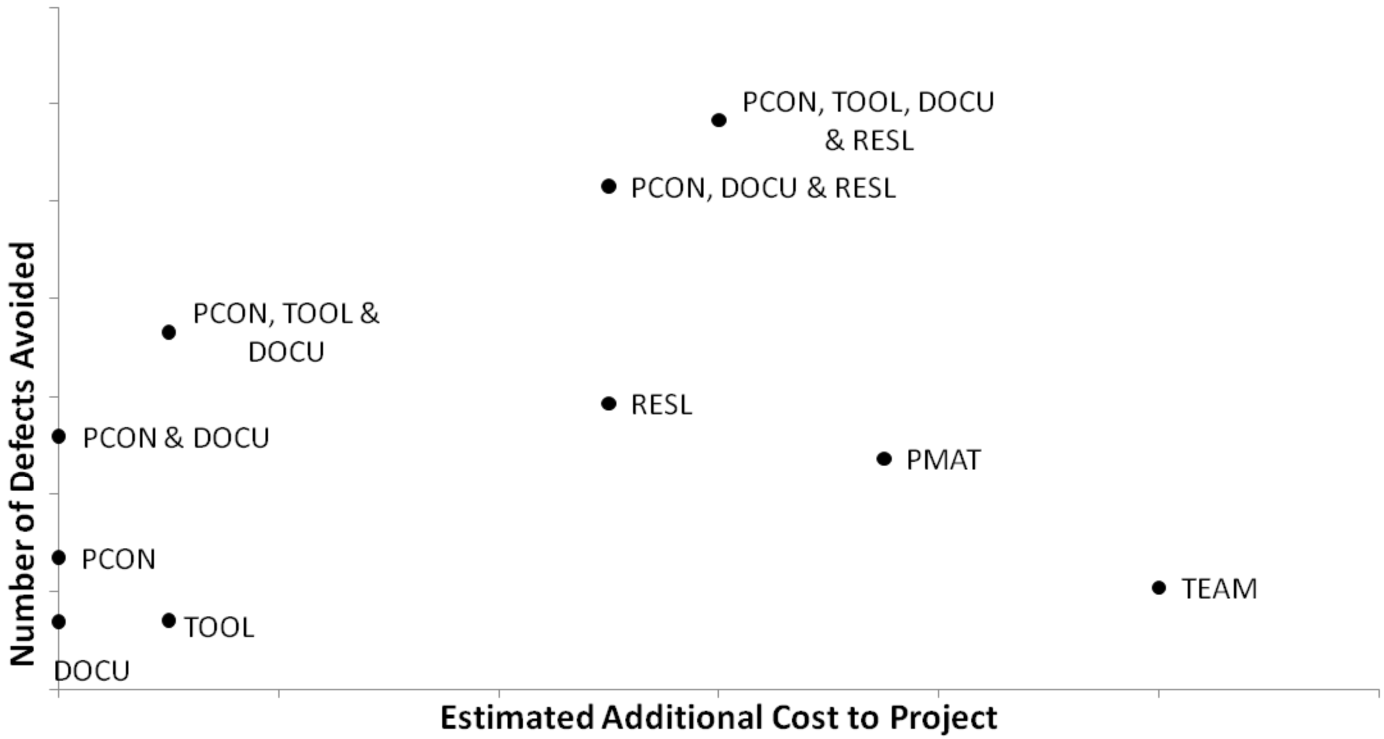
Study of Concurrent Processes



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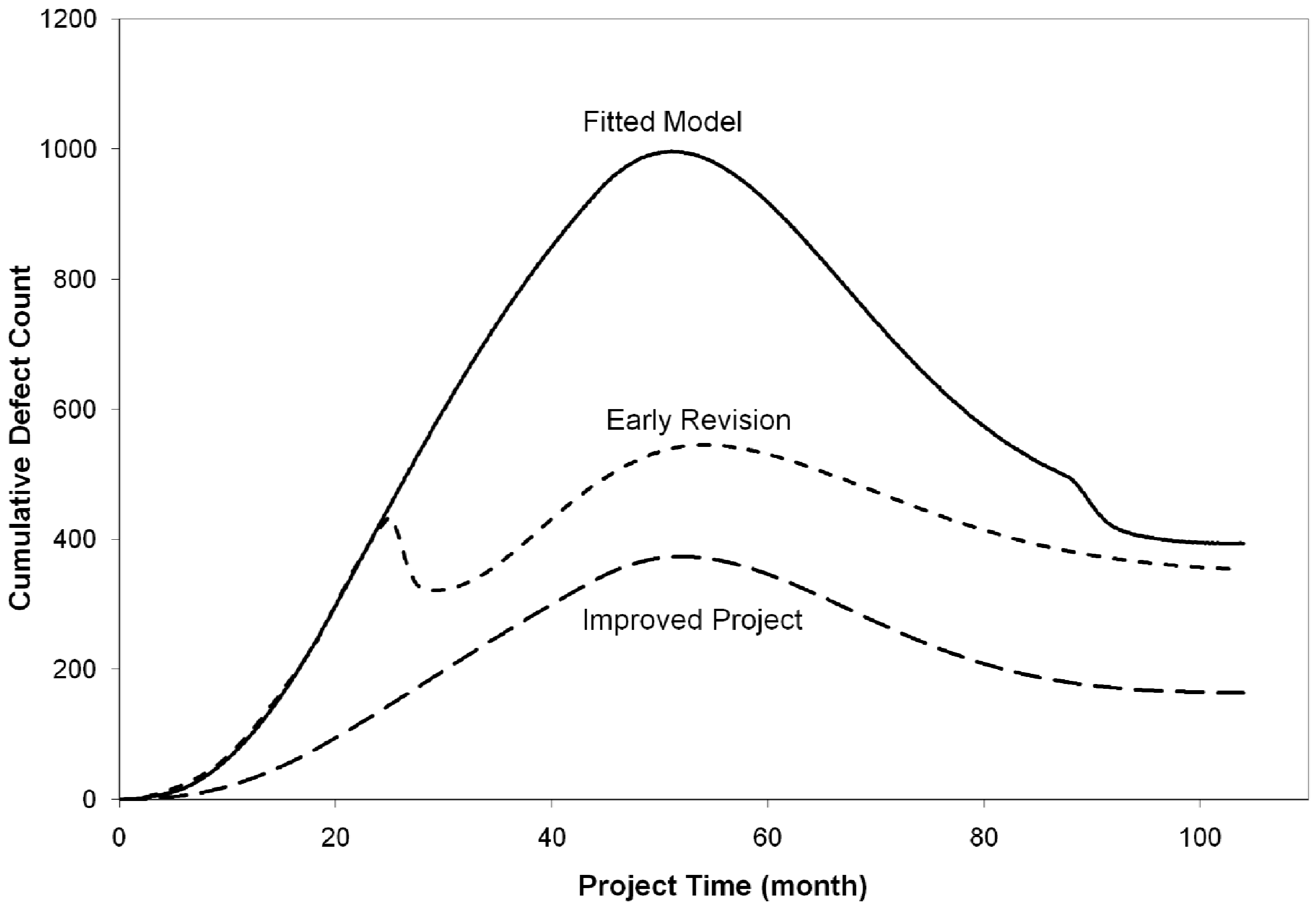

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Duration of Test and Fix Cycling

The difficulty of estimating test duration

- A discovery process versus an insurance process

A terrifying adventure into the unknown ⟷ Validating what we already know

- Some factors in test duration
  - *Amount of quality-inducing effort applied prior to testing*
  - *Type and complexity of software (including architecture)*
  - *Organizational knowledge of the product*
  - *Organizational discipline (change mgmt, SCM, build planning, etc.)*
  - *Types of testing required (high reliability requirements?)*
  - *Resource constraints (people/facilities)*
  - *Product (software, test cases, test tools) availability*
  - *Duration of individual activities*

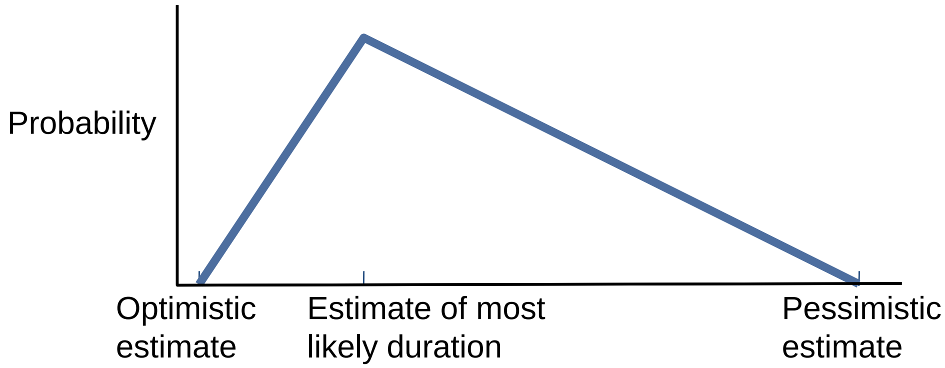
> Many factors contribute to software readiness

Previous Approaches to the Question

- Linear estimates

  Number of tests X Average time for each test = Total test duration

- Expert judgment plus Monte Carlo sampling



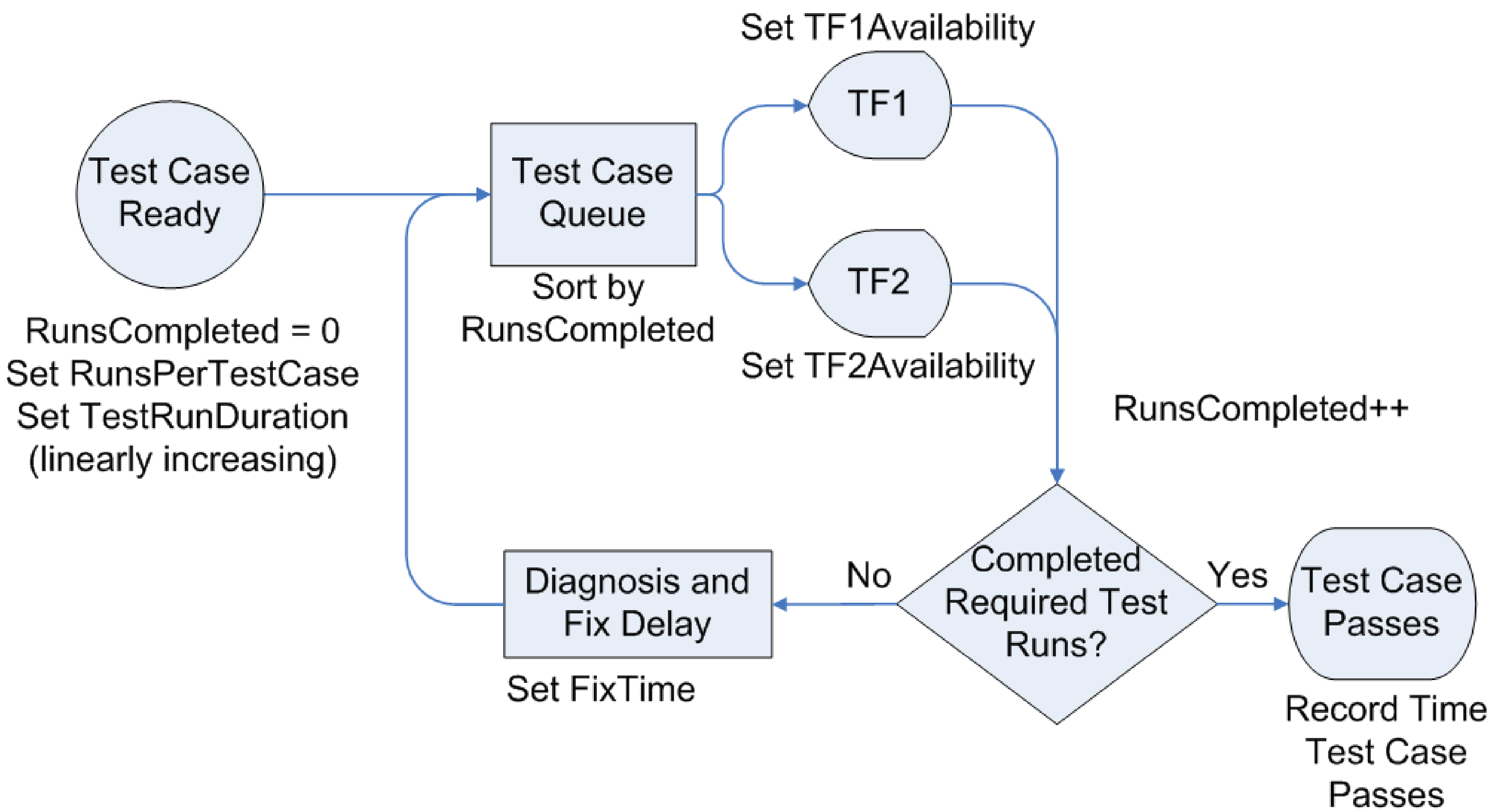
- Software project estimation tools

  Development Time** = 2.5 (Effort Applied)^b **[months]

Software project type	*b*
Basic	0.38
Intermediate	0.35
Highly-constrained	0.32

> Each of these methods has peculiar limitations

An example test-and-fix (TaF) duration model



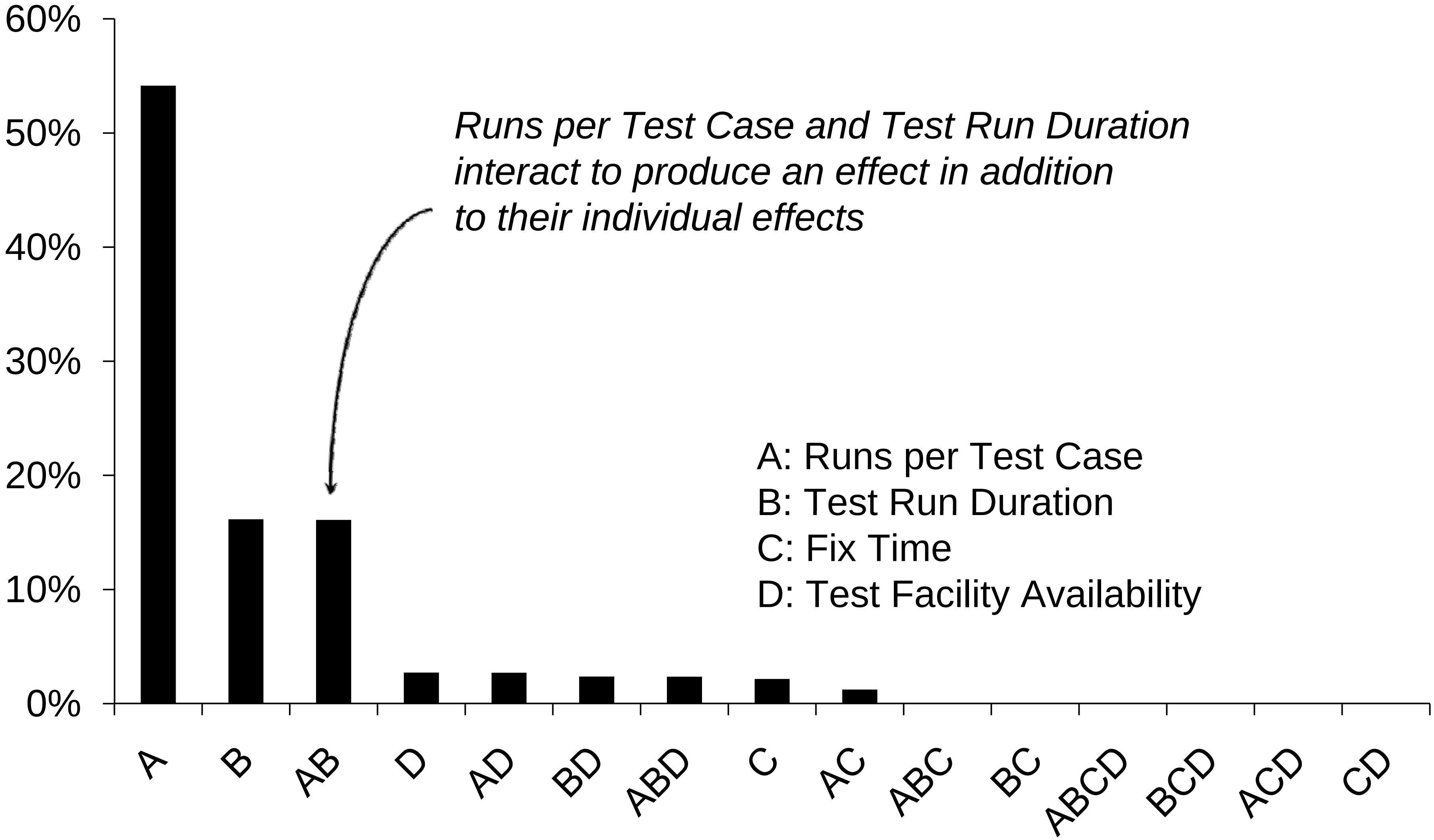
Discovering significant factors

- Used a full factorial experiment
  - *Use constant inputs representing expected operational values*
  - *All combinations of four factors at two levels each (2^4): 16 simulation runs*
  - *Response variable is duration of TaF process*

Factor	Low Value	High Value
Test Facility Availability	60 hrs/ week	100 hrs/week
Runs per Test Case	2	8
Test Run Duration	2 hrs	5 hrs
Fix Time	24 hrs	96 hrs

- Analysis of variance
  - *Calculate percentage contribution to variation in duration from sums of squares*

Significant factors



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Discovering behavior

- Used an additional full factorial experiment to produce response surfaces
  - *Focus on Runs per Test Case and Test Run Duration*
  - *Use one Fix Time value and two Test Facility Availability values*

Factor	**Values**
Test Facility Availability	60 and 100 hrs/week
Runs per Test Case	2, 4, 6, 8
Test Run Duration	2, 3, 4, 5 hrs
Fix Time	7 days

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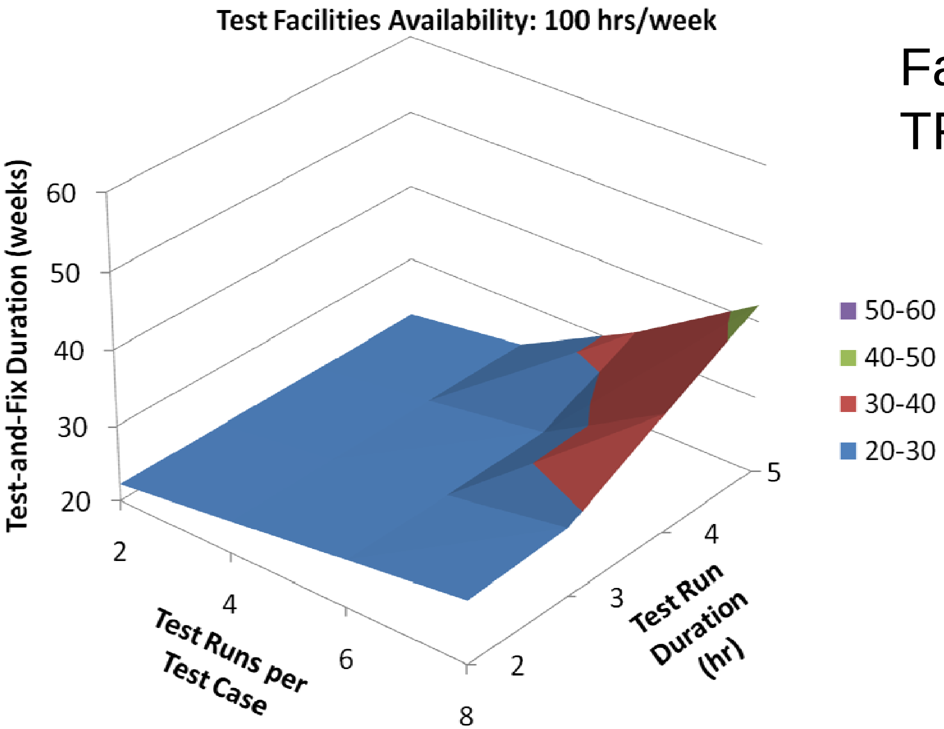
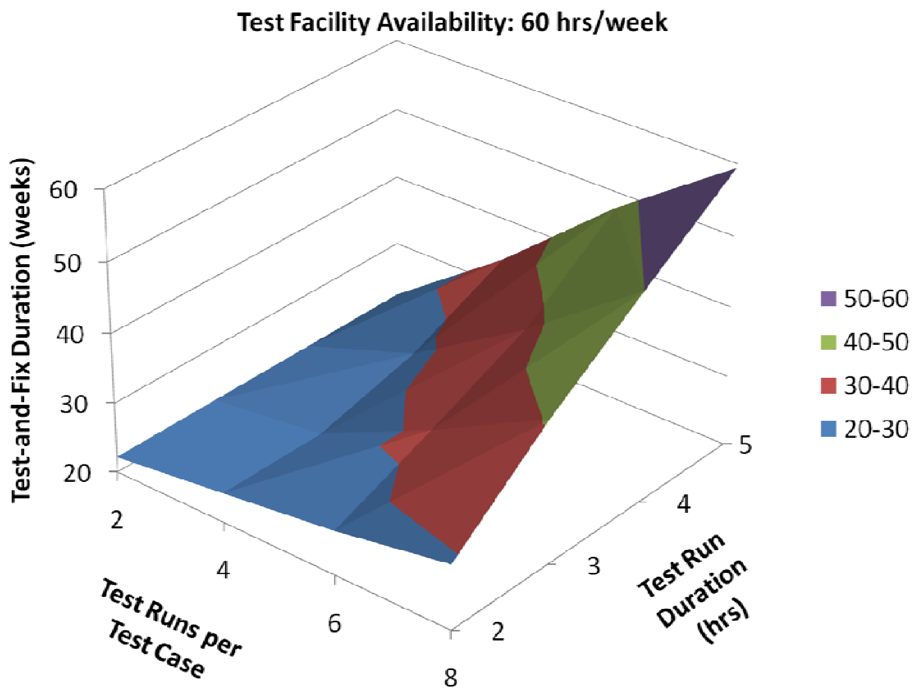
Behavior: the TF threshold



Factor interaction above the TF full utilization threshold



TF availability moves the threshold

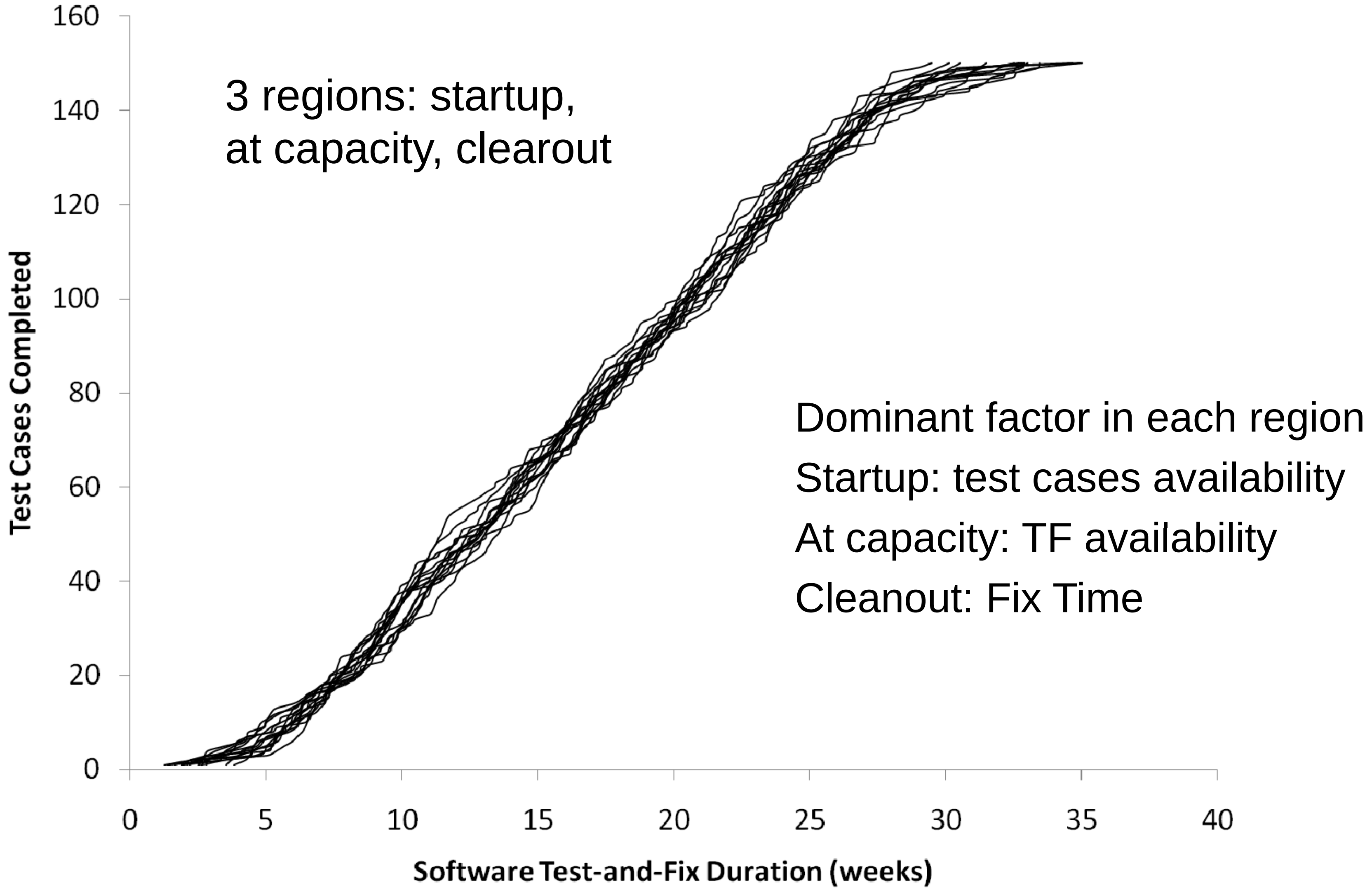
Modeling a likely scenario and alternatives

- Used likely inputs to estimate the duration of the test-and-fix cycle

Factor	Values	Sample
Test Facility Availability	Both test facilities at 40 hrs/week each	Constant for all simulation runs
Runs per Test Case	(2, .1), (3, .1), (4, .3) (5, .2), (6, .1) (7, .05), (8,.05)	Randomly for each test case in each simulation run
Test Run Duration	Triangular(2, 3.5, 5) hrs	Randomly for each test case in each simulation run
Fix Time	(7, .125), (8, .125), (9, .125), (10, .125), (11, .125), (12, .125), (13, .125), (14, .125) days	Randomly for each test cycle of each test case in each simulation run

- Alternative scenarios
  - *Additional test facility availability or an additional test facility*
  - *More optimistic Test Run Duration and/or Fix Time*

Test case completion times



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Findings and impacts

- Good, early estimate of test duration
  - *Eliminates re-planning activities*
- Identify the primary factor in test duration
  - *Focus on the real problem*
  - *Avoid expensive, inconclusive experimentation on the actual system*
- Understand system behavior
  - *Identify test management options*
    - Staffing levels
    - Test facility availability
    - Degree of overlap in test and reviews
    - Rate of taking test cases into TaF cycle
    - Order of test cases
    - Backlogging defects

> Actions supported by analytic underpinnings of statistical modeling

Acquisition Planning

Acquisition Seat Creation in the Concept Design Center

Process and Tool(s) Repeat for Each Concept/Configuration

Experience

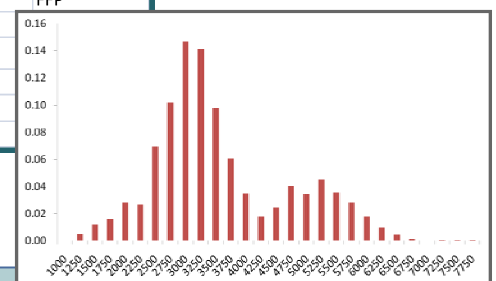
Reference Documents

1. DoD 5000.2
2. JCIDS 3170
3. FARs
4. DFARs
5. Defense Acq Guide

Topics	Choices Primary
Program Type	ACAT 1
1. Changes to basic Acquisition doctrines and processes	
a. Standard (large) Air Force program procurements	Standard
b. Standard procurements with ability to insert waivers	
c. New and special Acquisition doctrines	
i. "faster, better, cheaper"	
ii. Urgent needs and "DX" DPAS Priority	
6. Special considerations:	
a. Sole source pr[illegible]ement	None
b. For[illegible] suppliers	
[illegible]ont[illegible]s	FFP
Procurement	
Program Structure	

Preliminary Acquisition Strategy Panel

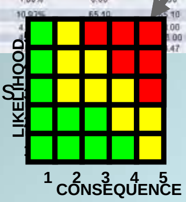
Acq. Seat



CDC

	Mass (kg)	Mass (lb)	% Dry Mass	Daylight Imaging	Eclipse Standby
		Time min-->		9.77	35.95
Payload Total	**154.85**	**341.44**	**39.72%**	**1,198.55**	**53.36**
Spacecraft	**267.94**	**590.81**	**60.28%**	**462.43**	**424.[illegible]**
Propulsion	7.03	15.49	1.80%	0.00	[illegible]
ADACS	42.63	94.00	10.9[illegible]	65.10	[illegible]5.10
TTC	19.13	42.19	4.[illegible]	[illegible]	[illegible].00
CDH	17.00	37.49	[illegible]	[illegible]	[illegible].00
Thermal	7.54	16.63	[illegible]	[illegible]	[illegible].47

- Technical Param's
- TRL
- Heritage

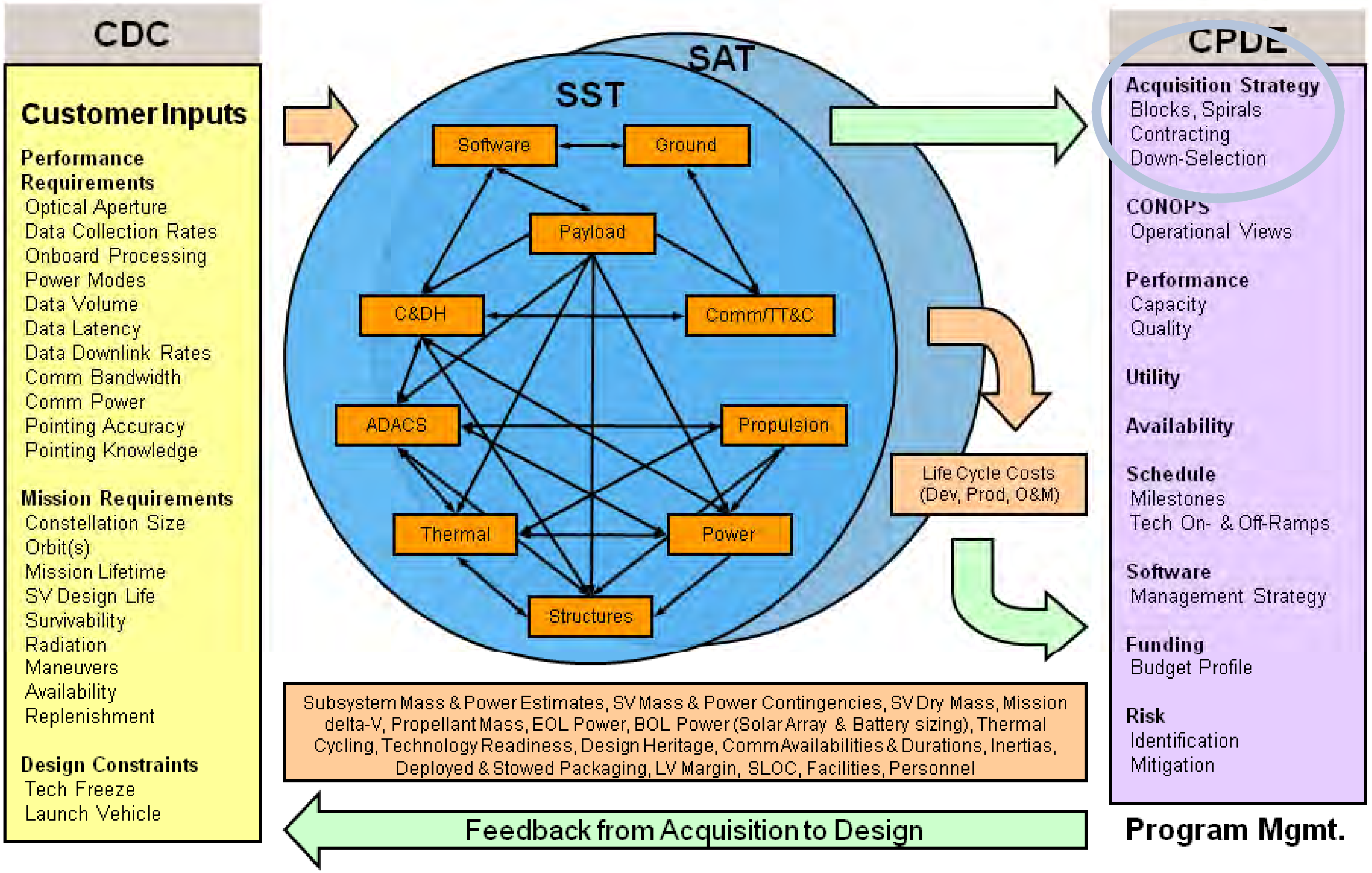


Acquisition Model

1.	Estimate of success of achieving Milestone C
2.	Time duration to Milestone C
3.	Issues and impediments to program success
4.	Time duration/success of alternative approaches

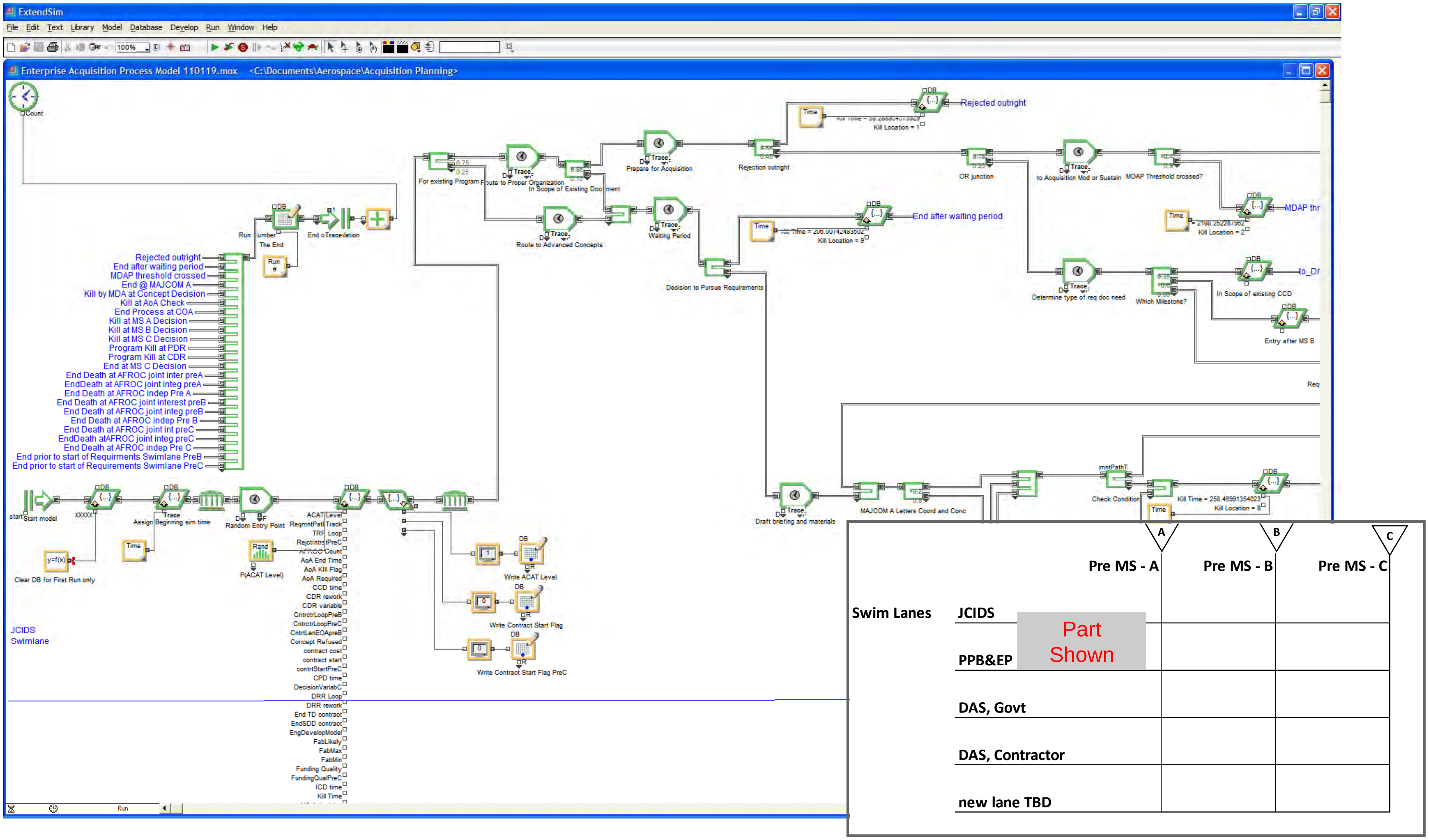
Concurrent Decision Support at Aerospace

*Concept Design Center (CDC) & Concurrent Program Definition Environment (CPDE)**



Acquisition Enterprise Model

Upper left hand portion of Model shown in detail



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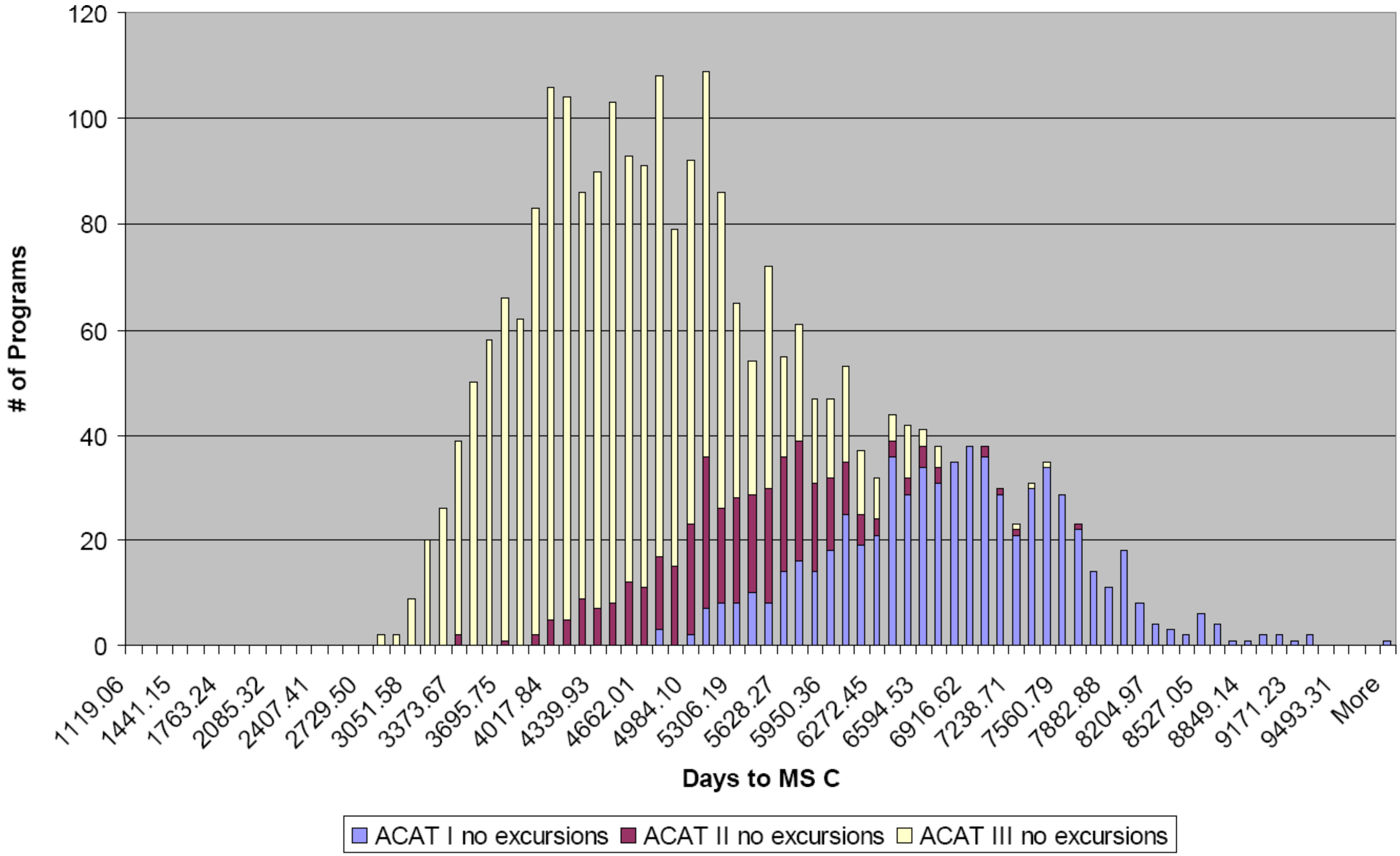
Histograms of Formal Process Time to MS C by ACAT

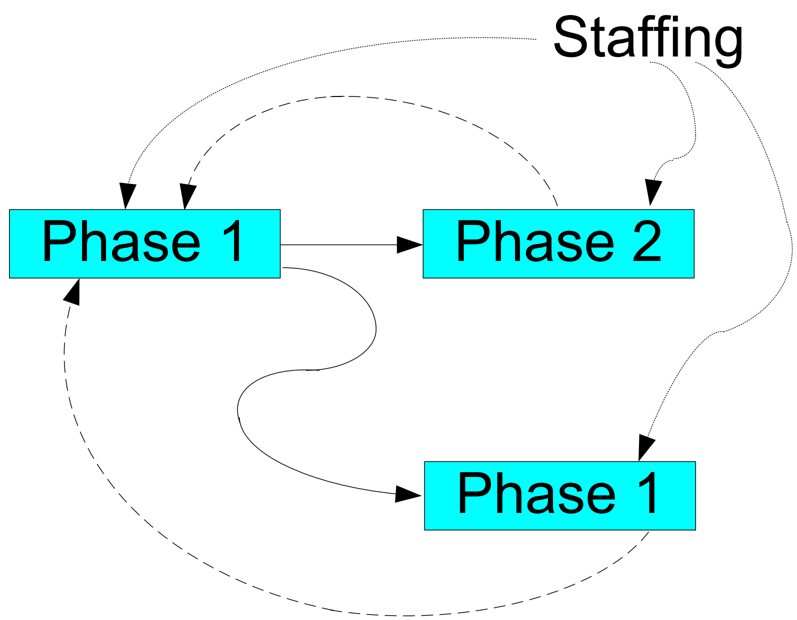


Study of Concurrent Processes

Phase Relationships Example

Leading increment

Trailing increment



Work available and inherited defects

Rework found in dependent phase

Staff allocation

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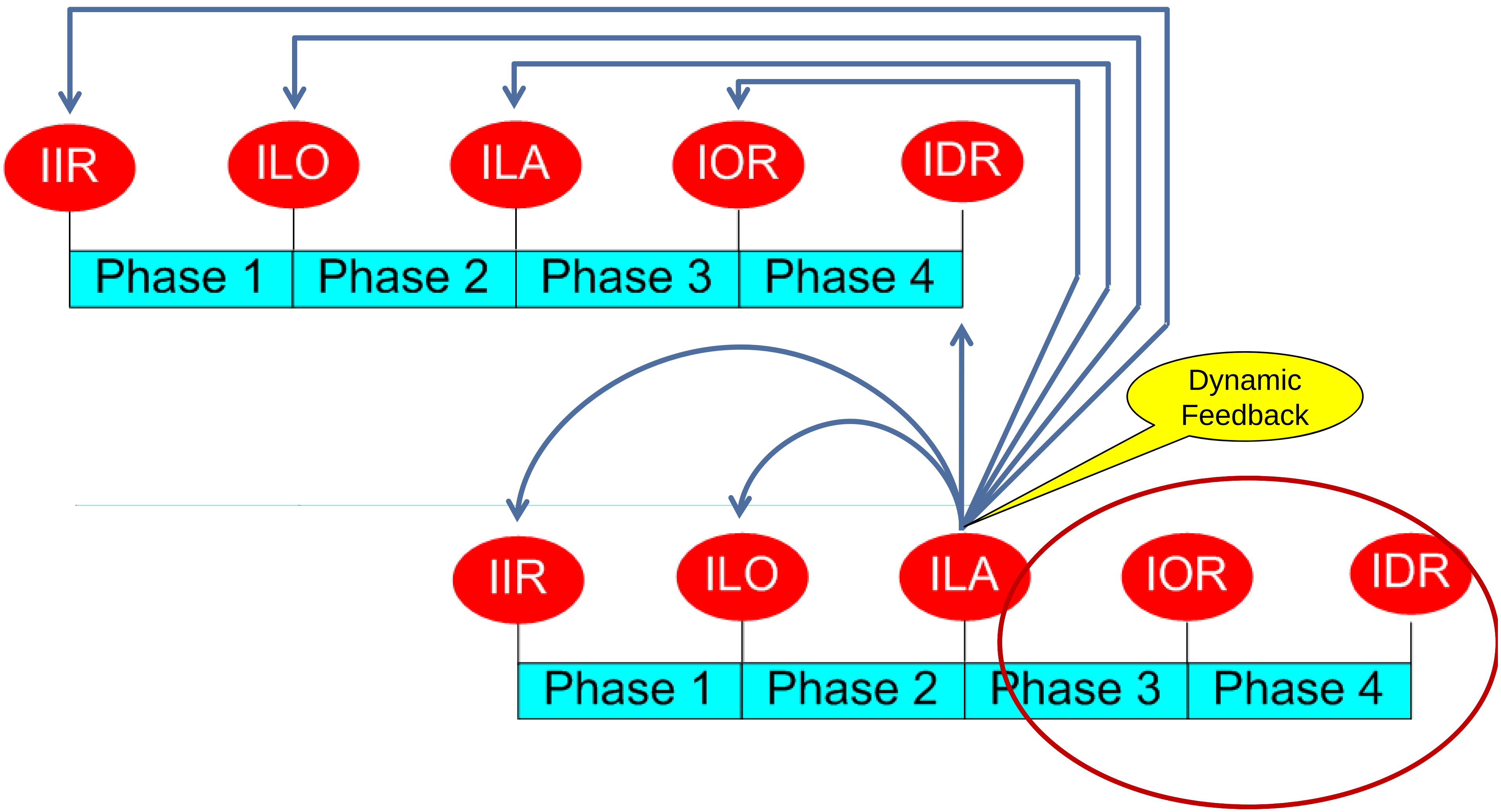
Rework Implications of Concurrent Engineering



> Potential regression at the "ILA" anchor of the Trailing Increment

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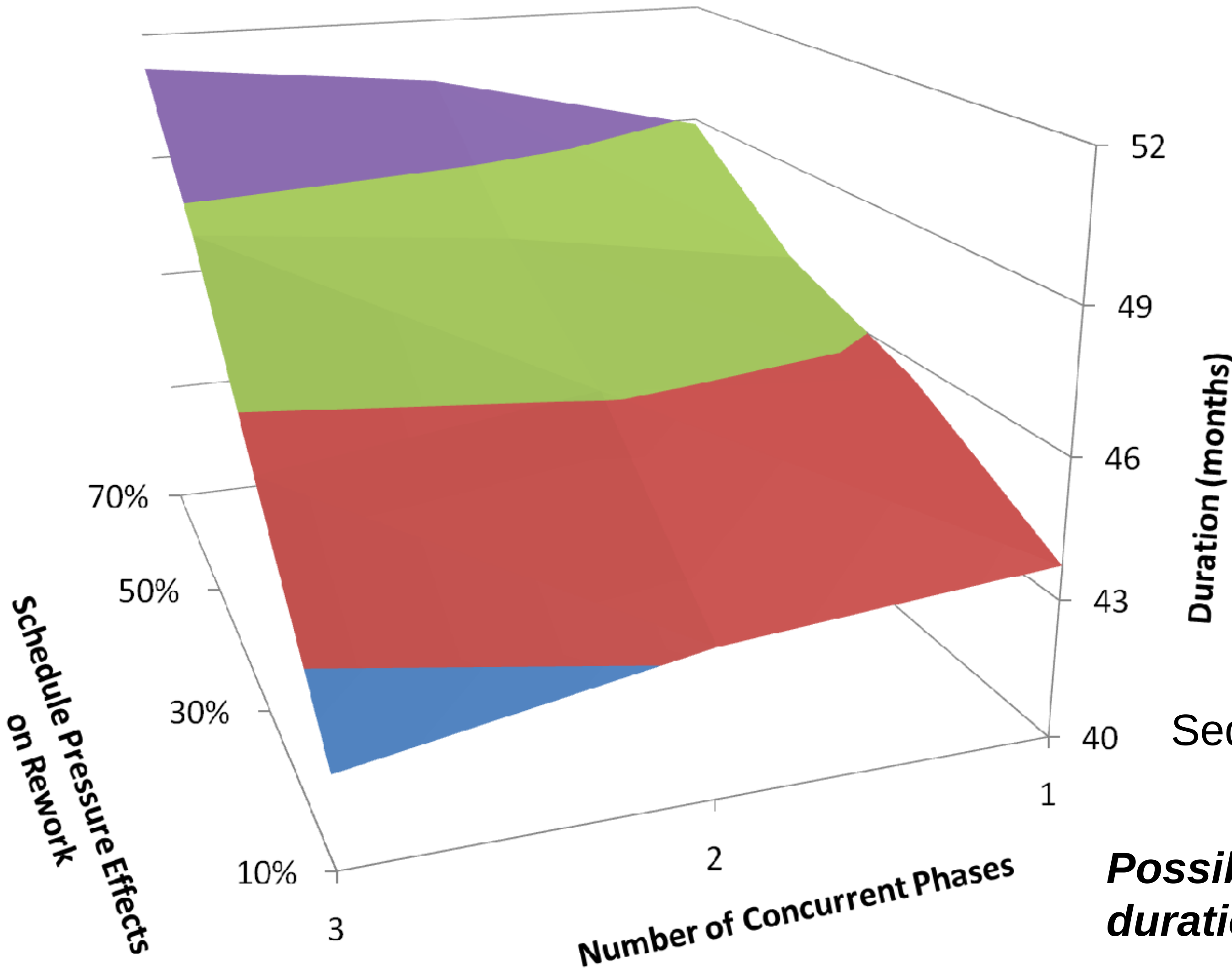
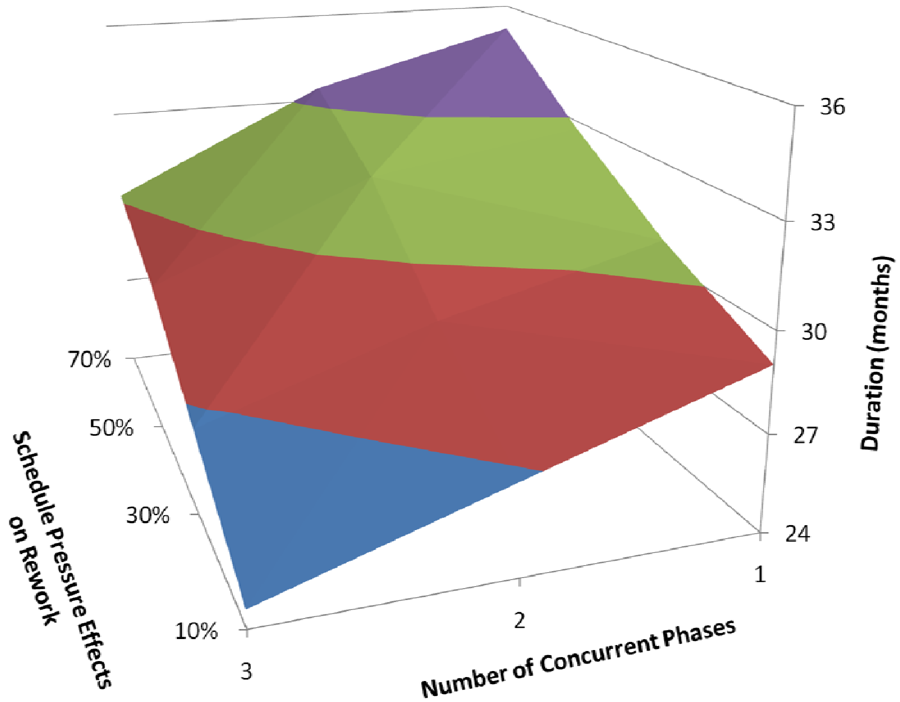
Duration



Sequential: 45 mo.

Possible 3 mo. duration reduction

> Duration risk increases with degree of concurrency



Duration in the Larger Staff Scenario

Double staffing

Duration reduced ⅓ to 30 months

Duration risk dramatically reduced

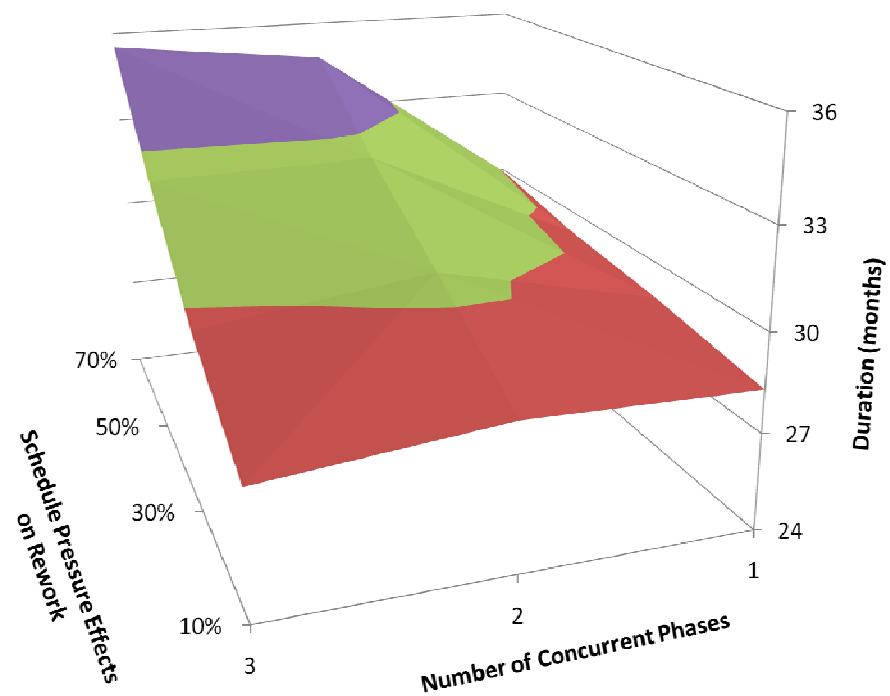
Duration in the Better Quality Scenario

Less defect introduction, better discovery

Duration reduced ~17 months

No duration benefit to concurrency

Duration risk substantially reduced



Conclusion

Experiential Lessons from Dynamic Modeling

- Dynamic modeling is useful, often necessary, for
  - *Gaining insight into the nonlinear processes of programs*
  - *Estimating outcomes*
- We are learning to use it in project management
  - *Asking the right question*
  - *When the cost is justified*
  - *At this point, limited engagements work best*
  - *Can be used to identify dominant process constraints*
- Valuable tool for research
  - *Across projects*
  - *Process concepts*

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